Colour Contrast Occurrence matrix: a vector and perceptual texture feature

Armando Martinez, Noël Richard, Christine Fernandez-Maloigne

Colour Contrast Occurrence matrix: a vector and perceptual texture feature

Martínez R. A. [a],[b], Richard N.[a] and Fernandez C.[a]

[a]University of Poitiers, XLIM-SIC UMR CNRS 6172, Bât. SP2MI Bd. Marie et Pierre Curie, Téléport 2, 86862 Futuroscope Cedex, France.

[b] ESIME-Zac. Instituto Politécnico Nacional, Av. Luis E. Erro S/N 07738, D.F. México.

ABSTRACT

Texture discrimination was the second more important task studied after colour perception and characterization. Nevertheless, few works explore the colour extension of these works and none for vectorial processing of this important visual information. In this work we propose a novel and vector processing for colour texture characterization, the color contrast occurrence matrix C_2O. This new texture feature is based on the colour difference assessment. To be link to the human perception, the colour difference is expressed using a perceptual distance expressed in CIELab and two angles characterizing the chromaticity and darker or lighter direction. Through this new attribute, we analyze the stability to changes in illumination, viewpoint and spectrum of the light source in front of different texture image databases . Thanks to our construction, we avoid the main limit of existing texture features requiring an initial colour quantization or a binarization inside the texture construction. Keeping the small local contrast, we obtain a more accurate texture feature description explaining the obtained results. Then we carry out the construction of a features vector by occurrence quantization, keeping the initial ideas of Julesz, Haralick and Ojala, for the classification purposes. The results show best correct classification percentages in databases that with important spatio-chromatic complexity as ALOT.

1. INTRODUCTION

Colour and texture are two visual characteristics highly important in low level image processing applications. However the definition of texture is linked to a human semantic meaning.[1] Researches from the point of view of human perception by Julesz,[2] Caelli[3] and Landy[4] have shown that texture assessment can be approached from local, structural approach or a combination of both. So, there is no formal mathematical definition for texture;[5] while the color rendering can be define mathematically.[6]

Haralick establishes the bridge between the physical and the computer point of view using statistical analysis between two pixels through the cooccurrence notion.[7] Later Ojala extends the study to the neighborhood using local binary patterns.[8] The initial idea, expressed for intensity images, was extended to colour by different researchers, which have tried to mix the color and texture separately,[9][10] or in parallel,[11].[12]

Many approaches are evaluated in databases where lighting conditions are controlled and therefore there is no significant changes in the appearance of texture. The invariance conditions of acquisition of an image are important since the appearance of natural textures vary significantly with changes in lighting.[13] Industrial or artificial textures have periodic structures that hard to change even if not, they can be seen from the same angle. The natural textures may not have any detectable periodic structure. However they are random, but repeated resulting in an apparent texture.[14]

Inside this work, we propose a new vector processing for colour texture characterization, the color contrast occurrence matrix C_2O. This new texture feature is based on the colour difference assessment. To be link to the human perception, the colour difference is expressed using a perceptual distance expressed in $CIEL*a*b*$ and two angles characterizing the chromaticity and darker or lighter direction.[15] Our paper presents the results of

Further author information: M.A. E-mail: armando.martinez.rios@univ-poitiers.fr, Telephone: +33 (0)5 49 49 65 11
R.N. E-mail:noel.richard@univ-poitiers.fr, Telephone: +33 (0)5 49 49 66 20
C.F. E-mail:christine.fernandez@univ-poitiers.fr, Telephone: +33 (0)5 49 49 65 73

evaluating the vector C_2O to changes in lighting, orientation and intensity of the light source. Varying spectrum and texture rotation, simulates different day light or artificial illumination[1] and allow to explore the impact on our 3D representation of the texture variations. In a second time, we show the results of the classification of C_2O against other approaches as cooccurrence matrices and local binary patterns adapted to colour domain.

2. METHOD

2.1 Colour Contrast Occurrence Matrix definition

Our feature express the probability to have a specific *colour difference* between 2 pixels separated by a spatial vector. This spatial vector is defined classically by a spatial distance and orientation. The colour difference is expressed in $CIEL^*a^*b^*$ through a perceptual distance ΔE and two angles. The first angle is defined on the ab plane characterizing the chromatic orientation of the colour difference. The second angle is defined between the colour difference vector and the ab plane characterizing if the difference vector expresses a darker or lighter difference. So the Colour Contrast Occurrence (C_2O) is defined by:

- be two pixels location: p_{ci} and p_{cj}.
  - associated to their colour coordinates (C_i, C_j), expressed in $CIEL^*a^*b^*$,
  - with $||\overrightarrow{p_{ci}, p_{cj}}|| = d$ and $\llcorner(\overrightarrow{Ox}, \overrightarrow{p_{Ci}p_{Cj}}) = \theta$.
- Then the Colour Contrast Occurence Value $\overrightarrow{\Lambda(C_i, C_j)}$ is:

$$\begin{aligned} \overrightarrow{\Lambda(c_i, c_j)} \quad : \quad & prob\Big(\overrightarrow{\Lambda(c_i, c_j)} = \overrightarrow{\Lambda_\chi}\Big), \\ & \text{with} ||\overrightarrow{\Lambda(c_i, c_j)}|| = \Delta E_\chi \\ & \text{ and } \llcorner(\overrightarrow{Oa}, \overrightarrow{c_i c_j}) = (\alpha, \beta) = \llcorner\overrightarrow{\Lambda_\chi}. \end{aligned} \tag{1}$$

2.2 Feature from the Colour Contrast Occurrence Matrix

Albuz et al. carried out a quantization from $CIEL^*a^*b^*$ space making a book of codes in order to reduce the information contained in a database.[16] Following this direction, we propose to construct the texture feature directly from the Colour Contrast Occurrence matrix. As the C_2O matrix creates a cloud of occurrences centered around the origin, the proposed features is the spherical quantization from center to the border of the C_2O cloud.

$$\begin{aligned} Sig_{C_2O}(I) = h_{\Delta_i \alpha_j \beta_k} \quad = \quad & \text{prob}\Big(\Delta_i \leq \| \overrightarrow{\Lambda(c_i, c_j)} \| < \Delta_j + \Delta E_{step}\Big), \\ & \text{with } \frac{\pi}{2n_\alpha}(j) \leq \alpha < \frac{\pi}{2n_\alpha}(j+1) \\ & \text{and } 0 \leq \beta < \frac{\pi}{n_\beta}(k+1), \end{aligned} \tag{2}$$

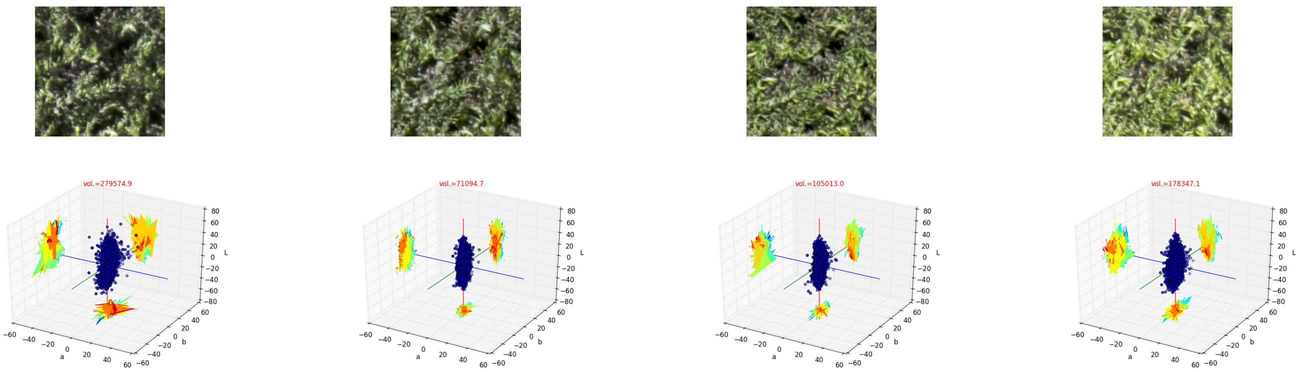
where ΔE_{step}, n_α and n_β are contrast norm, chromatic and lightning steps respectively.

3. RESULTS AND DISCUSSION

3.1 *C2O* Stability on illumination, rotation and view point changes for ALOT database

ALOT is an impressive colour image collection of 250 distinct rough textures, acquired by 4 different colour camera ($c = 1, \ldots, 4$). For each image and camera, six illuminations are considered ($I = (1, 2, 3, 4, 5, 8)$) and 4 rotations ($r = 0^o, 60^o, 120^o, 180^o$).[17] Three image sizes are proposed: full resolution (1536×1024), half resolution (768×512) and quarter resolution (384×256) pixels. The colour resolution is expressed on 24 bits.

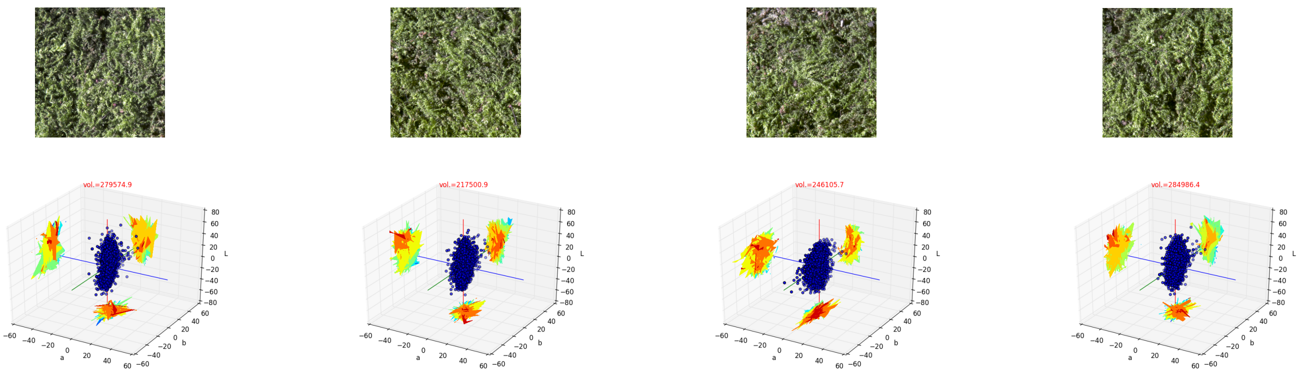
Images in the figure 1 show natural texture of grass in which only the illumination has changed (same camera ($c = 1$), the same viewpoint ($r = 0^o$)). Firstly, if we approximate the C_2O shape as an ellipsoid, few shape differences appear. The main ellipsoid orientation is organized around the L axis. Among the illuminant nature, the lightning difference varies from important (Illumination 1, due to a large range of contrast) to less important (Illumination 4). This fact is in adequation with our perception. In a more accurate observation, the illuminant variations induce change in the assessment of the chromatic difference observed on the ab plane, that is also in adequation with the physical construction of the observed scene as a multiplication of the illuminant spectrum by the reflectance spectrum. Inside this first study, we can take interest also to the bounding-box volume of the ellipsoid as a measure of the lightning impact on the scene.



illumination 1 | illumination 2 | illumination 3 | illumination 4

Figure 1. Impact on C_2O of illumination changes (image 110, ALOT database).

The second experiment assess the impact of the orientation changes on the C_2O feature. We select the same image than previously, selecting the illumination $I = 1$. The selected orientation to compare are ($r = 0^o, 60^o, 120^o, 180^o$). The results in figure 2 show that the C_2O shape is slightly modified, even if the volume measure is well preserved. The main ellipsoid axis keep the orientation among the L axis. A more accurate observation indicate that some problems appear in the ALOT process for the rotation change, The transform is not limited to a simple rotation but include also a translation. This problem is visible for the rotation $r = 120^o$, where the background appear and is not present on the others images. Consequently the C_2O shape is impacted by this texture part, that is not present in the other images.



Viewpoint 0^o | viewpoint 60^o | viewpoint 120^o | viewpoint 180^o

Figure 2. Viewpoint changes for image 110 ALOT database.

3.2 $C2O$ Stability on illumination and view point changes for OUTEX database

To assess the impact of lightning change in the OUTEX case, we use the TC0014 suite including 68 colour texture images of size 746×538 pixels of 24 bits acquired under three types of illumination: 2300K horizon sunlight

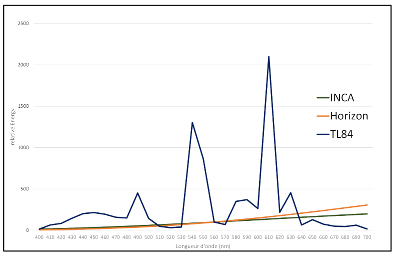
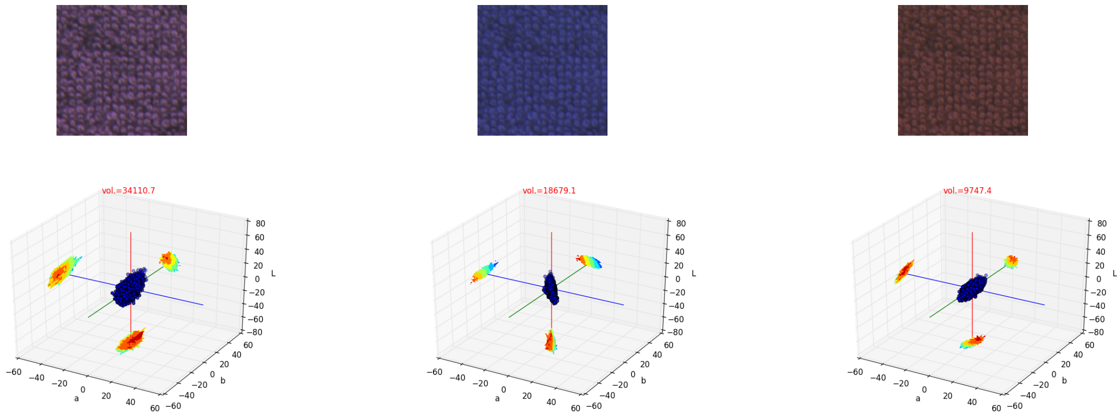


Figure 3. Spectra of the illuminant for OUTEX database (from OUTEX website)

denoted as "horizon", 2856K incandescent CIE A denoted as "inca" and 4000K fluorescent TL84 denoted as "TL84".[18] Figure 3 show the used illuminant.

In figure 4 we show the important variations on the content perception induced by the lightning changes. Among the illuminant, the canvas appear violet, blue or close to a brown in function of the spectral multiplication between the light spectrum and the reflectance spectrum of the canvas. These differences are explained by the variations in the red part of the spectra. In a first approximation, we expect that the C_2O matrix rotates around the L axis. This fact is obtained between the INCA and TL84 cases. As the HORIZON illuminant present a relative spectral power close to 550nm, as the INCA illuminant, the two ellipsoid have the same orientation. The difference are due to the differences in the spectrum shapes.



inca TL84 horizon

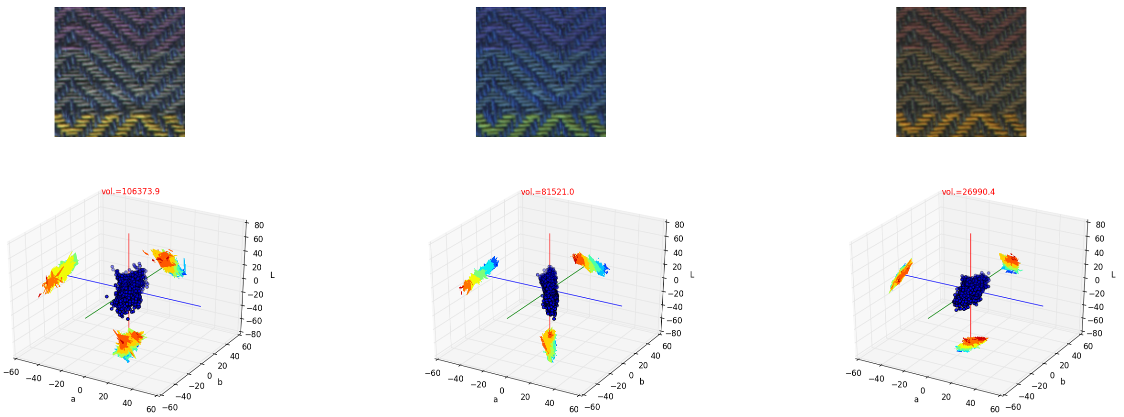
Figure 4. Variations in the illumination spectrum in the image canvas 2 outex.

For a more complex texture, as in the case of CANVAS 20 (fig. 5), the same interactions between the lightning changes and the texture generate the same C_2O modifications, even if the colour content is more complex. Such result induces the ability to identify the light modifications between two textures. In a second level of observation, the C_2O matrix are sufficiently different to allow the discrimination between the two CANVAS textures.

Inside the new extended OUTEX, the set TC0030 provides 68 images of colour texture of 128×128 pixels with different rotation angles ($0^o, 5^o, 10^o, 15^o, 30^o, 45^o, 60^o, 75^o$ and 90^o). The illumination conditions are the same for the 12240 images.[19] The graphic 6 shows the texture CANVAS 0 with rotations of $0^o, 5^o, 10^o$, 15^o. As in the ALOT case, the transformation applied to the image is not a pure rotation, and a translation appears also. Unfortunately the texton size is close from the image size so the translation induces some texture feature modifications. Nevertheless the C_2O shapes are similar and the obtained volumes are in the same range(outside the second case (5^o)).

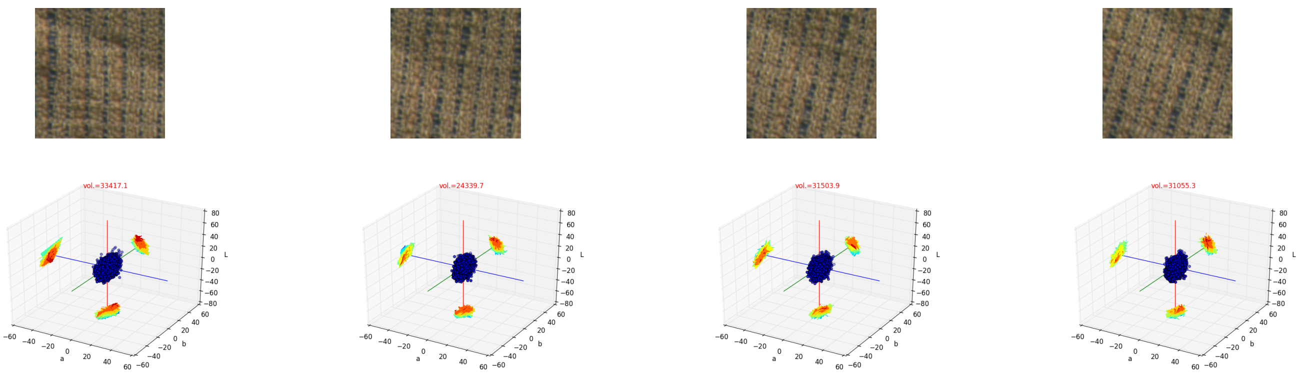
3.3 Illumination and viewpoint direction performance

After this subjective comparison, we develop an objective test to assess the feature stability among different variations. To do it, we use the classification schema suggested by Arvis.[11] First we test the ALOT database.



horizon inca TL84

Figure 5. Variations in the illumination spectrum in the image canvas 20 outex.



viewpoint 0^o viewpoint 5^o viewpoint 10^o viewpoint 15^o

Figure 6. Viewpoint changes for image canvas 0 OUTEX database.

The suite is cropped in two parts; the train set are the first 200 samples defined as $c(1,4)$,$l(1,4,8)$ and $r(0,120)$; and the test set is composed for the same samples with $c(2,3)$,$l(3,5)$, $r(0,120)$, $c3l2(0,120)$ $c2l2r0$ and $c1ir0$),[1].[5] The table 1 shows the correct classification percentage between C_2O and approaches invariants to lighting changes as cooccurrence (GLCM) and local binary pattern (LBP). These approaches including the colour and texture information in parallel (Cross-Channel Marginal Approach).[15] C_2O obtain the better score with a gain of 2% on the LBP approach. The second test is processed on the OUTEX extended database, the 12440 images were divided in 50% for train set and 50% for test. We mixed all angles variations. Table 1 show that other time C_2O has the best correct classification percentage in front of LBP and the cooccurrence.

	Coocurrence	LBP	C_2O	difference
alot	48.22	63.72	65.8	2.08%
outex	70.4	85.3	87.87	2.57%

Table 1. Comparison of correct classification score in front of viewpoint modification.

3.4 Illumination spectrum and rotation performance

Using the TC00014 from the OUTEX database, we obtained 1380 sub-images with 3 different lighting therefore 4080 sub-images forming 68 class of 60 samples each. The classification scheme was driven using 50% of the sample for the training and 50% for the classification.[20] Table shows that the C_2O feature obtains the better performance in face of the LBP, the two features presenting larger score than the cooccurrence.

	Coocurrence	LBP	C_2O	difference
outex	54.01	86.37	85.4	0.9%

Table 2. Comparison of correct classification score in front of illumination changes.

4. CONCLUSIONS

In this paper we presented a new way to include the texture and colour informations, based on the Julesz's and Haralick's contributions in the computational sense and on the results of Drimbarean and Palm in colour and texture. The Colour Contrast Occurrence matrix C_2O is processed in $CIEL^*a^*b^*$ to obtain a correct behavior in front of the human vision and kept the idea of the occurrence but translated into a normalized colour difference.

The results have shown that with the limits induced by the two selected databases, ALOT and OUTEX, the C_20 features shows good performance of stability in the recognition of texture under various viewing point or illumination changes. Local Binary Pattern obtains close scores due to a similar construction based on the local difference assessment.

An important aspect of this feature lies in the fact that the C_2O feature construction produces a dense feature, by opposition to the cooccurrence. As we have shown, the relationship between the color and the texture is directly understandable. At this step, the used feature is a spherical quantization of the three-dimensional clouds. In current works, a modelization is developed to reduce the feature size and improve the classification rate.

REFERENCES

1. Vácha, P., Haindl, M., and Suk, T., "Colour and rotation invariant textural features based on markov random fields," *Pattern Recognition Letters, Elseiver* **32**, 771–779 (January 2011).
2. Julesz, B., "Visual pattern discrimination," *IRE Transactions on Information Theory* **8**, 84–92 (February 1962).
3. Caelli, T. and Julesz, B., "On perceptual analyzers underlying visual texture discrimination: Part i," *Biological Cybernetics* **28**, 167–175 (1978).
4. Landy, M. S. and Graham, N., "Visual perception of texture," in [*THE VISUAL NEUROSCIENCES*], 1106–1118, MIT Press (2004).
5. Aptoula, E., "Extending morphological covariance," *Pattern Recognition* **40**, 4524–4535 (2012).
6. A., W. B., [*Foundations of Vision*], Sinauer Associates Inc., 1 ed. (1995).
7. Haralick, R., Shanmugam, K., and Dinstein, H., "Textural features for image clasification," *IEEE Transactions on systems, man and cybernetics* **SMC-3**, 610–621 (1973).
8. Ojala, T., Pietikäinen, M., and Harwood, D., "A comparative study of texture measures with classification based on feature distributions," *Pattern Recognition* **29**(1), 51–59 (1996).
9. Mäenpää, T. and Pietikäinen, M., "Classification with color and texture: jointly or separately," *ScienceDirect, Pattern Recognition* **37**(11), 1629–1640 (2003).
10. Drimbarean, A. and Whelan, P., "Experiments in colour texture analysis," *Pattern Recognition Letters* **22**(10), 1161 – 1167 (2001).
11. Arvis, V., Debain, C., Berducat, M., and Benassi, A., "Generalization of the co-occurrence matrix for colour images: Application to colour texture segmentation," *Image Anal Estereol* **23**(I), 63–72 (2004).
12. Porebski, A., Vandenbroucke, N., and Hamad, D., "Lbp histogram selection for supervised color texture classification.," in [*ICIP*], 3239–3243 (2013).
13. Burghouts, G. J. and Geusebroek, J.-M., "Material-specific adaptation of color invariant features," *Pattern Recognition Letters* **30**(3), 306 – 313 (2009).
14. Backes, A. R., Casanova, D., and Martinez Bruno, O., "Color texture analysis based on fractal descriptors," *Pattern Recognition* **45**(5), 1984 – 1992 (2012).
15. Martinez Rios, A., Richard, N., and Fernandez-Maloigne, C., "Alternative to colour feature classification using colour contrast ocurrence matrix," in [*International Conference on Quality Control by Artificial Vision QCAV 2015*], SPIE, ed. (2015).

16. Albuz, E., Kocalar, E., and Khokhar, A., "Quantized cielab* space and encoded spatial structure for scalable indexing of large color image archives," in [*Acoustics, Speech, and Signal Processing, 2000. ICASSP '00. Proceedings. 2000 IEEE International Conference on*], **6**, 1995–1998 vol.4 (2000).
17. Hossain, S. and Serikawa, S., "Texture databases - a comprenhensive survey," *Pattern Recognition Letters* **34**, 2007–2022 (Febraury 2013).
18. Oulu, U., "Outex texture database (www.outex.oulu.fi/index.php?page=classification)." http://www.outex.oulu.fi/index.php?page=classification (2002).
19. Lille1, U., "Extended outex texture classification test suites (http://lagis-vi.univ-lille1.fr/datasets/outex.html)."
20. Negri, T. T. and Gonzaga, A., "Color texture classification under varying illumination," *Worshop de visao computacional* , 61–66 (2014).